June 28, 1968

Director
Advanced Research Projects Agency
Washington, D. C.

Attention: Dr. Glen Finch

Subject: Semi-annual Technical Report of Research under Contract No. F44620-C-0099 for the period 1 January 1968 to 30 June 1968 - Sponsored by Advanced Research Projects Agency ARPA Order No. 966

Dear Sir:

Enclosed is a progress report of research activities under subject contract for the period 1 January 1968 to 30 June 1968.

Very truly yours,

Michael I. Posner
Professor, Psychology
Acting Principal Investigator

MIP: mke

Enclosures

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SEMI-ANNUAL TECHNICAL REPORT OF RESEARCH
UNDER CONTRACT NO. F44620-67-C-0099
FOR THE PERIOD
1 JANUARY 1968 TO 30 JUNE 1968

CODING SYSTEMS IN PERCEPTION AND COGNITION

This report will review the second six months of our contract research. Like the first semi-annual report, this one will cover a wide diversity of research topics and experiments. However, there does seem to be an increasing unity underlying the efforts of our group. One focus is on the levels of processing which occur during the first few seconds after presentation of a stimulus. A second aspect is an interest in the analysis of meaning as it relates to familiar tasks such as listening and reading.

Before beginning a detailed analysis of the experimental studies, it would seem useful to review some more general contributions arising out of our joint efforts. Three papers completed during this six months seem to typify efforts of our group to look outside individual research projects in order to sense and organize developments in the field at large. Attneave has prepared a paper for a symposium on Anthropoligical Research to be held this July in Austria. His paper deals with questions of the functional utility of consciousness. Beginning with human processing limitations, Attneave attempts to develop the consequences of these limitations for broader social problems. He suggests the importance of evolving a collective consciousness which would provide some of the functional capacities for the body politic which individual consciousness provides for the single organism. A copy of this paper is included.

Our last report mentioned that Keele had begun a paper reviewing 50 years of research into the control of motor movements. Keele's work emphasizes an important trend in experimental psychology. There have been two recent books in the area of motor control and a renewed emphasis on the motor theories of perception and cognition. These motor theories are more sophisticated than those which were developed in the early part of this century. They rely not upon peripheral motor activity but upon motor programs, which may be entirely within the central nervous system. These ideas provide increasing contact between certain parts of physiological psychology and work in human performance. During this period, Keele's paper was completed and submitted to the Psychological Bulletin. Some idea of the favorable reception that this paper is likely to receive can be obtained from a letter which Keele received from the editor. The editor quoted from his consultant as follows. "This is an excellent and long overdue review of the motor side of skilled performance. I am enthusiastic in recommending publication, and I predict it will be a best seller on reprint requests."

Another effort to look beyond the confines of our own laboratory is represented by a paper to appear in Science Year, an annual publication of the World Book Encyclopedia. This book reviews developments in the various sciences during each year. Posner has attempted to outline some

of the important developments in experimental psychology during the past year. While there have been previous articles appearing in Science Year in the area of psychology, concentration has been primarily in the field of mental health, animal, and physiological research. In fact, human experimental psychology has been poorly known by the public and there have been relatively few attempts to indicate some of the excitement and transition in this field which has taken place during the last few years. It is hoped that this article may serve to interest students and laymen in these developments.

Another contribution which our contract has sought to make is in the development of a topical information retrieval system. One of the complaints most frequently heard in the experimental psychology is the difficulty of developing a method of structuring the field which will aid students and research workers and serve as a means for classifying previous results. Because of the scope of our contract and the presence of investigators in a variety of different fields, we have attempted to develop a joint retrieval system. It has begun with a rather small list of topics in the various areas which are covered by the contract. As new issues of the Psychological Abstracts become available, we have attempted to classify articles under these topic headings. Individual investigators have been responsible for topics close to their fields of interest. As additional articles become available, the subtopics and structure of the area is to be developed by the particular investigator. It is expected that as the topic file grows it will be possible for other investigators to obtain an overview, as the person primarily interested in that field sees it, by looking at the subtopics and abstracts in that section. A copy of the topics presently used in the file has been enclosed. It will take several years for us to develop sufficient experience for a formal evaluation. While meant primarily for our own purposes, it is hoped that some of the ideas which come out of our effort to develop such a file will be of use to others.

In late April we received the computer ordered under this contract. The PDP-9 was installed and operable on 24 April. In accordance with our previous plans the first experimental system is now running on the computer. This first set of experiments is in conjunction with analyses of schema formation and abstraction reported under the section on cognitive processes. It is expected within the next six months a large number of additional experiments will be in progress using the PDP-9.

The bulk of the accomplishments during the last six months, however, have been centered in experimental analyses and theoretical statements of our major research teams. As before, these have featured work in perception and psychophysics, performance and memory, and cognitive processes.

I. PERCEPTION AND PSYCHOPHYSICS

This six months has seen the publication of the paper mentioned in the last report by Fagot and Stewart (1968) on the comparison of two types

of psychophysical functions. During the current research period, Fagot and Stewart have continued to analyze the basis of the psychophysical law. To do this, they have developed a number of psychophysical techniques which may be somewhat more analytic to understanding the basic axioms underlying psychophysical functions than merely plotting magnitude estimates against intensity. They measured both the ratio of perceived intensity of light pairs presented simultaneously and perceived differences between simultaneous light pairs. These data allow tests of two basic axioms for magnitude scaling called the product law and the additive law. The data showed some support for each of these basic axioms. Perhaps of greatest interest is that Ss who violated these axioms still obeyed the power law, indicating that the scale form is not in itself sensitive to violations of the basic axioms.

The goal of this research is to provide a precise basis for classifying fundamentally different coding systems for perceptual continua. The distinction between prothetic (quantitative) and metathetic (qualitative) continua has been an important one in psychophysical research. More fundamental methods for analyzing differences between judgments on different continua could provide a better behavioral means of separating the coding mechanisms of single dimensions.

Fagot and True have initiated a project to extend magnitude estimation techniques to judgments of warmth and cold. The importance of this particular continuum lies in the fact that discriminability between forms of the power law depend on the size of the threshold. For low thresholds, the different forms are about equivalent and the larger the threshold the easier the discrimination. During this period an apparatus has been built which allows manipulation of the temperature delivered to the hand of the S. It is hoped that experiments during the next quarter will allow clearer separation of the phi and psi versions of the power law.

Attneave has been trying to develop an analysis of the structure and function of cognitive maps. During the present period Attneave and Benson have completed some experiments on the spatial coding of tactual stimulation. Six vibrators are arranged in a T-formation, three positioned horizontally above, and three vertically below. The S places three fingers of one hand on the upper vibrators, and three fingers of the other hand on the lower ones. Vibrations to the various fingers are then paired with letters of the alphabet over a number of learning trials. These are followed by a transfer situation in which S's hands exchange places, and in which he is asked either to give the same responses to the same fingers (Group F) or the same responses to the same vibrators (Group V). These results are shown in Figure 1. When S's eyes are open, transfer performance (in terms of response latency) shows considerable decrement in the case of Group F, but little or none in the case of Group V, indicating that associations are predominantly to locations in physical space. In a comparable experiment with blindfolded Ss, however, both groups show decrement to about the same degree. These results indicate that the representation of physical space

into which tactual stimulation is mapped is strongly visual in character. The use of a transfer task and a reaction time measure has been explored in other experiments by Attneave and Olson (1967) and seems to provide a sensitive method for teasing apart cues used in perceptual judgments.

In a recent masters thesis Eichelman (1968) used a reaction time technique to explore the early stages of perception of figures. The first experiment compared reaction time for same-different judgments using stimulus populations consisting of letters and single line slopes. Eichelman reasoned that if letters were,as has been pointed out in much physiological (Hubel & Wiesel, 1965) and behavioral literature (Hebb, 1963), considered as a bundle of line elements, they would be matched more slowly than single lines. In order to control discriminability, Eichelman used only four slopes, horizontal, vertical, left and right, oblique. The results of his study clearly indicated that the letters were matched as fast as,if not faster than,the individual line slopes. Recently he has pushed this analysis in a signal detection framework. Using brief durations, he has measured d' for letter and slope "same-different" judgments as a function of stimulus duration. Very preliminary results seem to indicate that slopes are more discriminable than letters at low duration, while at higher durations letters seem to be somewhat more discriminable than slopes. This result has led Eichelman to propose tentatively that visual information from a letter builds up differentially for individual lines. However, in the matching task he suggests that the slopes are matched as a unit. During the next quarter, it is likely that Eichelman will be able to collect sufficient data on the descriminability question to give this interesting hypothesis a more complete test.

Eichelman has also begun to use the reaction time method to explore the ability of Ss to ignore certain parts of complex figural stimuli. His technique was to present a single letter for a variable period of time from 50 to 500 msec. At the offset of this letter a second letter is presented and the S is required to say if the two letters are "same" or "different" as rapidly as possible. The letters may be on either a red or green background. The Ss need not attend to the background but are instructed to respond "same" if the two letters have the same name. The results obtained so far are interesting. For a physical identity match (e.g., AA), there is interference with reaction time when the background is changed. This is particularly true at low durations. When the match has to be based upon the name of the letter (e.g., Aa), the change in background has no effect. Eichelman interprets these results tentatively as indicating that Ss have difficulty removing noise information from the stimulus at short exposure durations. He hopes to use techniques of this type to investigate the details of coding of a visual stimulus immediately after presentation.

Another use of the reaction time technique has been to investigate the role of familiarity in perception. In his thesis Eichelman presented Ss with strings of letters two, four or six units long. He found that the

time for a physical match increased with the number of letters in the string but to a lesser degree if the letters formed words than if they were nonsense (see Figure 2). Other aspects of the data indicated that the Ss were not reading the words but that the match in all cases was done at the physical level. Presumably the familiarity of the common letter sequences aided the development of the physical match particularly as the length of the string increased.

Using a different technique, Reicher (1968) and Snyder (1968) have also explored the role of familiarity in perception. Reicher (1968) in his doctorial dissertation showed that following a very brief tachistoscopic flash, recognition of one letter is better when the flash was a four letter word than when the flash contained only a single letter. Moreover both the letter and the word showed superior recognition than four unrelated letters. Reicher interpreted these data as meaning that the familiar word is recognized as a unit. A paper describing this work has been submitted for publication and is included (Reicher, 1968a).

Snyder in his masters thesis used a technique developed by Hershenson (1968). He exposed letter strings varying in approximation to English. One of the letters of the string could be mutilated by cross hatching. For every trial, a critical letter was marked by a vertical bar. The S responded by naming the letter he saw under the bar. If the letter was mutilated, the S was given three choices as to which of the particular mutilated forms he saw. This was done in order to distinguish between two possible roles which the familiar context might play. It might have helped the Ss "see" the critical letter or else it helped provide him information which helps to identify but not to "see" the letter. The results show no effect of approximation to English on either the accuracy of report of the critical letter or the accuracy of identification of the correct mutilation when the correct letter had been reported. Thus this technique provides no clear evidence for familiarity effects on the early stages of perception.

Posner (1968) has attempted to classify the results of familiarity on perception based primarily upon visual matching tasks. His conclusions, to be reported in a forth coming chapter, suggest that familiarity has no effect upon a single unit within a visual matching task. Thus there is no difference between the time to report "same" to two familiar letters as against the time to report "same" to two unfamiliar Gibson figures. However, when the stimulus array consists of a string of units, familiarity does have an effect. This indicates that the familiarity effects are in the integration of successive visual units. Unit here is defined on the basis of experiments like Eichelman's and indicates only that subelements within the pattern are matched no faster than the pattern itself. This conclusion handles data from reaction time and threshold matching techniques using both letters and forms. His analysis also distinguishes matching tasks from those in which S must identify the stimulus based upon past experience (Reicher, 1968a).

We are beginning to develop methods to discover where in the sequence of processing the effects of prior learning should be expected. As we learn more about familiarity effects, it will be possible to fragment processing stages as occuring prior to or following familiarity operations. Perhaps this fragmentation of the processing sequence will turn out to be more effective than the usual separation between tasks which are called perceptual and those which are said to involve memory. As will be seen in the next section, it has been very difficult for us to make distinctions between perceptual experiments and memory experiments.

II. MEMORY AND PERFORMANCE

Memory

Reicher has completed a series of studies on interference mechanisms in short term memory. His experiments involve a list of words presented aurally at rapid rates. List interference was varied by the number of rhyming words occurring during the list. Interference at the time of recall was manipulated either by having the two alternative recognition words rhyme or not rhyme. These manipulations allowed Reicher to discriminate between two general hypotheses concerning the role of interference. According to the list interference hypothesis, interference is effective during the period of time between the presentation of an item and the test. According to the comparison hypothesis, the interference operates only at the time of recognition. The results suggested that the primary effect of interference was to increase the strength of irrelevant response alternatives during the retention interval. This result was interpreted as being most favorable to the incremental list interference hypothesis of Shepard (1961) and opposed both to the decremental list interference hypothesis of Posner (1967) and to comparison interference theories (Postman,1964). A paper containing these results has been submitted to the Journal of Experimental Psychology and a copy is enclosed.

Reicher has continued this work by exploring the forgetting function in experiments of the same type as those reported above. He used a retroactive inhibition design where either similar or dissimilar words were interpolated between the presentation of a critical word and the recognition test. He found that the differences between similar and dissimilar groups were greatest at the shortest retention interval. As retention intervals increased, both the similar and dissimilar groups showed losses in retention but the difference between the two groups tended to decline. During the next quarter, Reicher hopes to extend this forgetting function method to look at designs which involve proactive interference. In such designs the similar words occur prior to the critical word. They make it possible to explore very short delay intervals and to observe the growth or decline of interference effects over time.

Another experiment using somewhat the same logic was run by Reicher using single letters rather than words and visual presentation rather than auditory presentation. Under these conditions, there was a great deal of variability among Ss but no significnat differences as a function of acoustic similarity. This result raises distinct problems with the generally accepted view that visually presented material are interpretated into an acoustic code during presentation. Studies of recall of visually presented material have given consistent evidence for the acoustic translation hypothesis. However, there has been great difficulty in obtaining evidence from recognition experiments that visual material has been translated into an acoustic form. It is possible that the representation of visually presented information in memory only gives strong evidence for acoustic transformation in cases where S is required to actually recall the stimuli. This would be expected if visual memory systems were available to store such information.

Our group has been active in the study of visual memory processes. Yet our studies of visual memory have not indicated capacity sufficient to account for storage in tasks like those of Reicher. An example of the limitations of visual memory is apparent in a recent experiment conducted by Reicher. He replicated experiments reported earlier by Glucksburg and Ballagura (1965) in which Ss were presented with a complex array of letters. After the array disappeared, there was a cue which indicated which of several lines of letters they were to report. In Glucksburg's work there was no evidence for improvement on non-cued lines even after many dozens of exposures. Reicher speculated that the reason for this was because the tone cue,which was used in these studies,provided no relevant information to allow S to retrieve the previously presented information. In his study Reicher provided three of the four lette of the repeated item as a cue and still got no increase in performance on the remaining letter even after this particular line had been presented 10 times as a non-cued row. This experiment gives striking evidence that visual material presented and stored in a short term sensory store is not retained.

The last report outlined a series of studies by Posner and his associates on retention of visual information from a single letter.. Using a reaction time technique it was possible to get retention of the visual form of a letter for periods of time between 1 and 2 sec. following presentation. These studies also provided some evidence that the retention of the visual aspect of the letter could be improved if S was induced to concentrate upon it. Moreover, they suggested that the S could generate a visual code from the name of the letter. These results have now been written in monograph form and submitted for publication in the Journal of Experimental Psychology. A copy of the paper is included with this report.

In his Masters Thesis, a portion of which was presented to the recent W.P.A. meetings, Boies has explored the conditions for rehearsal and generation of visual information. He has shown that concentration upon the visual form can lead to improved matching out to 2 seconds. However,

this appears to be quite difficult for Ss, either because the system which mediates this activity fatigues, or because a lapse of attention leads to a loss of the visual representation from a readily accessible store. Boies has also shown that it is possible to obtain selective interference with the name component of the letter by providing Ss with letter names to retain during the match. This increases the time for name matches, without changing the time for physical matches. Boies also explored the effects of leaving a letter present in the visual field for durations up to 1.5 secs. Surprisingly the time for a physical match immediately following the first stimulus tends to increase with the longer exposure durations, but the time for a name match starts to decline. It is as if Ss tend to shift attention to the lower case of a letter when the upper case is left present in the visual field. These results will be included in Boies M.A. Thesis which should be avilable by late summer or early fall.

While we continue to explore conditions for successful rehearsal and generation of visual information, a main effort during the last six months has been to study arrays longer than one letter. The first study of this type (Posner & Taylor, 1968) compared retention of one, two and four letters. After the array was presented, the Ss had a delay interval of 10, 500, or 1500 msec.,and a single probe letter was presented in the position of one of the letters in the array. The Ss task was to say whether the probe letter had the same name as the letter previously appearing in that position. On some of the trials the letter was physically identical and on other trials it was not physically identical but had only the same name. As the number of letters in the array increased, the availability of visual information at the two left positions was constant. These two positions show reaction time for physical matches about 50 msec. faster than name identity matches after the shortest delay interval. However, in the four letter arrays, the two positions right of center give no evidence of visual information by our criteria, even immediately after stimulation.

In order to explore this phenomenon further, arrays were used which varied in visual and acoustic similarity. All the arrays consisted of three letters. The middle letter of the array could be a G, C, or D which served as the target letters. The context could be either visually similar to the target letters (O and Q), acoustically similar (Z and V), and neutral (M and R). Two experiments showed that the visually similar arrays increase the time for physical identity matches,but did not affect the time for name identity matches. This result implies that during the time when the array is present, the S stores both a visual and auditory code of the letters. If the auditory code was not separate from the visual code, it would be expected that any operation which affected the physical match would also affect the name match. Not all letters which are presented visually seem to produce a visual code by our criteria. This suggests that the visual code which we measure is not a passive result of visual stimulation but some more active process. It also seems to follow from our results that the Ss can interrogate either the visual or the name

code. Exactly how this interrogation takes place is a matter which is not yet clear. The most likely method seems to be for S to determine the case of the letter which is being presented as a probe. If the letter is upper case, he then interrogates the visual code while if the letter is lower case, he interrogates the name code. Some evidence for this hypothesis is available within the experiments. A full report of these experiments and their implications is to be presented at the Donder's Centenary Symposium in Eindhoven, The Netherlands in August, 1968. A complete version of this paper is included (Posner & Taylor, 1968).

Taylor has been trying to study the properties of the system which integrates current sensory information with previously stored stimuli. His studies involve presenting a single stimulus followed after three seconds with a stimulus pair. One stimulus of the pair is a probe and Ss task is to respond as rapidly as possible whether the probe is the "same" as either the stimulus in memory or the other member of the pair. Taylor has shown that for familiar forms (letters) and unfamiliar forms (Gibson figures) and for colors that RTs are faster when the probe matches the stored information. This tendency increases with practice. When the probe matches both the stored stimulus and the other member of the pair, RTs are even faster. Taylor is trying to determine if the system which does the matching has access to the sensory context and stored information simultaneously or whether it must deal with one at a time. The results of these studies will form the basis of Taylor's doctoral dissertation which should be available by fall.

A good deal more work needs to be done in order to bridge the gap between visual stimulation and visual memory. It seems that the data that we have obtained in the last several years completely eliminate the possibility that all visual information is stored in the form of auditory instructions. Moreover, it does appear that at least for one or two seconds after the presentation of a visual stimulus a visual code is set up which preserves a good deal of the topological properties of the previous visual stimulation. In a chapter currently under preparation for inclusion in the third volume of Advances in Learning and Motivation, Posner has attempted to review evidence of the relationship between visual stimulation and visual memory. Although the evidence is still rather slim, there are some interesting possibilities emerging from experiments. Of particular interest is an attempt to tie in the current visual stimulation with what might be called an "abstract idea" built up from past visual experience with similar stimuli. The chapter tries to link studies of the type presented in this section with those on schema formation presented in the section on cognitive processes.

The last report summarized work by Keele on motor memory. Keele found that the retention of kinesthetic information of short movements required the presence of central processing capacity, while longer movements did not seem to require such capacity. This finding has been corporated in a paper which has been accepted for presentation to the 16th International

Congress of Applied Psychology (Posner & Keele, 1968). A copy of that paper is included with this report.

K. has begun to prepare apparatus for following up his work on motor memory. A recent book by Howard and Templeton (1966) outlined the physiology of muscle spindle and joint receptor mechanisms and their relationship to kinesthetic judgments. Keele hopes to use this information in designing new experiments which will look at the psychological retention characteristics of information mediated by these different systems. In order to do so he has designed apparatus both for wrist rotation movements, which involve heavy emphasis on joint receptors, and for pressure responses, which presumably involve primarily muscle spindles. By using the interpolated tasks worked out previously (Posner, 1967) he hopes to tell whether these receptors place differential loads upon central processing capacity.

Performance

One connection between work on memory and performance is in the study of repetition of the same response system. A number of recent investigations in our laboratory have concerned the question of repetition.

Keele has been studying the repetition effect in choice reaction time. For many years it has been known that reaction time to an immediately repeated event is much faster than to a non-repeated event (Hyman, 1952). Because this appears to constitute a departure from the normal decision making mechanism, there has been considerable interest in determing the basis of this so called repetition effect. Keele's first hypothesis was that the effect depended on short term memory. However, experiments showed that neither increasing the intertrial interval nor interpolating a irrelevant task between successive trials affected the repetition effect. This indicates that the repetition effect is not due to a short term memory mechanism. Further experiments, in which Ss actually predicted which stimulus was to occur next, indicated that the effect was due to some behavioral hypotheses formed by the S about what response was most likely to follow. Thus, the normal decision making mechanism was bypassed because S was expecting a particular stimulus-response combination. The results of this experiment have been written and submitted to the Journal of Experimental Psychology and a copy is enclosed with this report.

Reicher has studied the repetition of information in long strings of letters. The S is required to shadow visual letters at very rapid rates. Unknown to him at certain positions within the shadowing task, the same sequence of letters is repeated. In the previous semi-annual report, Reicher had shown that errors in shadowing decline when the same sequence of letters was repeated during the list. He has since replicated this phenomena but the effect is very small and does not show up under all conditions. Reicher hopes to obtain conditions where the effect is somewhat stronger so we can use it as a measure of decay and interference effects in memory. Instead of requiring the Ss to recall

the previous stimulus, he can use improvements in their performance as a measure of the strength of the trace laid down by the previous stimulus sequence. This technique would bring even closer the relationship between studies of memory and those of perceptual motor performance in general.

Recently Kornblum (1968) has proposed that the repetition effect may account for the relationship between information and reaction time found in many studies of choice reaction time. His proposal stems from experiments with very short interstimulus intervals of about 50 msec. However, his generalization extends to discrete trial studies in which the times between successive stimuli ranges up to 10 sec. There is considerable question about whether his analysis could be reasonably applied to these situations. If his analysis is correct, much of the theory built around the relationship between information and reaction time would have to be replaced. Given Keele's results on the repetition effect, Kornblum's position would indicate that the relationship between reaction time and information was primarily due to guessing techniques. Hyman has undertaken to test the Kornblum hypothesis within the standard discrete choice reaction time situation. His data indicate that with repetition held constant, there is still a relationship between information and reaction time. Thus he believes that the Kornblum's effects can not be extended to account for the standard choice reaction times situation. Hyman's experiments were conducted in Bologna as part of his Fullbright research position at that University. His paper on the relationship between choice reaction time and information will be presented at Donder's Centenary Symposium in Eindoven in August. At present, we do not have a copy of this paper to include with our report but it will be forthcoming subsequent to the Centenary.

Keele and Ells (1968) have completed studies of the psychological refractory period which was described briefly in the last report. They found no evidence that separate decisions can overlap in time. However, they found significant departures from the usual psycholgoical refractory period results. In particular when the first decision is quite difficult, the second decision is delayed more than would be expected on the basis of the time for the first decision. In this case decision making mechanisms seem to be genuinely refractory rather than merely unavailable during the period of time that the first stimulus is being processed. Keele and Ells also believe that their data suggest a tendency to switch to another task as the primary task becomes more difficult. This result would have interesting implications for psychological research on a number of fronts if in fact it is borne out by more detailed analysis of the data. Keele and Ells are preparing a report of their work on the psychological refractory period which should be available shortly.

Posner and Keele have been pursuing a series of experiments on the processing of feedback information during movements. The first experiment

of this series (Keele & Posner, 1968) has been published. Although this experiment was completed prior to the initiation of the contract, it does set the stage for experiments performed under this contract. The experiment explored the time for processing visual feedback. It was found that if a movement was faster than 190 to 250 msec., the presence of visual information about the location of the target did not aid the S in performing the movement.

Posner has developed a method for assessing the feedback components of more complicated movements. In this technique S rotates a pointer from one target to another. At some position in the movement, white noise which is being presented to the S, is interrupted. The S's response to the offset of the white noise is to press a telegraph key as rapidly as possible. Reaction time to the offset of the white noise is used as a measure of the depth of attention to processing of the feedback from the movement. This technique is based upon an extension of the psychological refractory period and divided attention techniques.

One result obtained from comparing visually guided movements to large and small targets is shown in Figure 3. This experiment was reported to the Western Psychological Association, 1967. It shows that the depth of attention to the movement is a function of the position of the signal within the movement and varies depending upon the target size to which the S is moving. Posner, Cox, and Keele studied movements which were visually guided or had no visual information, and which were either to externally located targets or to targets which the S had memorized. A series of functions for the different types of movements were obtained. It was shown that kinesthetic movements to external targets required little or no attention from the S. On the other hand, kinesthetically guided movements to memorized targets required a good deal of attention during the movement. A formal report of this work is included in a paper by Posner and Keele (1968) to be presented at the 16th International Congress of Applied Psychology, a copy of which is enclosed.

Posner has also been attempting to analyze automated movements. In his situation Ss are required to move back and forth between stops. The work presented above suggests that such movements require little if any attention from S. By this criterion, it could be said that such movements were outside of attention or required no central processing capacity. It is of interest to ask whether movements of this type could be interferred with by secondary tasks. It has been long supposed (Keele, 1968) that automated movements are not subject to interference from secondary tasks. Some people have suggested (Keele, 1968) that automated movements like golf swings or playing a musical instrument, etc., benefit when S's attention is not placed upon characteristics of the movement.

To explore these ideas, Posner developed a secondary task which involves S maintaining a constant pressure on a telegraph key. If S places too much or too little pressure on the key, white noise is presented. Since the

critical position can be very small (.01 "), this is quite a demanding task. A strain gauge is used to sense the signal,which is amplified and recorded on an oscillograph.

Only a preliminary analysis of these pen recordings have so far been made. A few examples of some of the results are shown in Figure 4. It seems clear from the data analyzed so far that there is interference between the secondary task and some components of the primary movement task. An analysis of the effect on different components has not yet been completed. The pause time appears to be most affected by the secondary task. The movement cycle (movement time + pause time) is changed much less by the secondary task. We are also using this method to investigate interference with motor memory when, for example, the primary task does not have external stops but must be executed from memory. It is hoped that within the next several months more detailed analyses of the records will be obtained. During his stay in England on an NSF Postdoctoral Fellowship, Posner hopes to analyze these data further and explore other techniques to study automated movements.

It is apparent both from Keele's review of the literature on skilled movements and from much of the work presented in this section that the study of movement must emphasize the question of central control. In that sense studying movements can aid in understanding cognitive processes. In fact, a recent article by H. L. Teuber (Eccles, 1966) has indicated that the study of voluntary movements is as fruitful an arena for the investigation of the structure of human information processing as the field of perception. It is hoped that the work of our group can play a role in the development of this area of psychological research.

III. COGNITIVE PROCESSES

It is as difficult to separate the area of cognitive processes from studies of performance as it is to separate memory from perception. However, in the work of our laboratory the emphasis within the cognitive processes area has been in concept formation and utilization, and comprehending of natural language. These two topics of research are greatly overlapping, and one goal of our work is to make the former serve as a model in the analysis of the latter. Thus, we hope that our studies of schema formation and dimensional concept utilization will provide some of the analytic tools necessary to isolate mechanisms involved in extracting meaning from written or spoken discourse.

Concept Formation

Some of our early studies of schema formation (Posner & Keele, 1967) were included in the last report. In the current period we have replicated the effect of a week's delay upon retention of the schema and individual memorized patterns. Two experiments have been written and submitted to the *Journal of Experimental Psychology*, in a paper entitled "Retention of

abstract ideas", a copy of which is enclosed. It should be noted that a similar experiment using our materials and methods was conducted recently at the University of Minnesota (Strange, Keeney, Kessel, & Jenkins, 1968). They obtained results quite similar to those presented in our paper.

Our previous report presented some experimental plans by Frost for extending the work on schema recognition. An initial experiment along this line has been completed. Frost used lists containing two levels of distortion and prototypes in a running recognition memory experiment. The Ss were required to say whether or not they had seen each successive dot pattern. Frost found that the probability of reporting a prototype as "old",after having seen several of its distortions,was as great as the probability of correctly reporting that he had seen a pattern before. This finding indicates that the Ss are not merely able to classify the prototype correctly,but also think it is something they have seen before. Several aspects of Frost's data are less clear. For example, he was not able to develop a systematic function relating change in probability of correct recognition to the lag between the presentation and representation of a pattern. Nor was there a clear difference between level 5 and level 7 distortions. One of the reasons for the ambiguity of some of Frost's data is the relatively few distortions which he was able to use with his procedure. The computer can now plot the dot patterns directly on the oscilloscope display. This will allow Frost to use large numbers of distortions and lag conditions. It is hoped that within the next six months, Frost will be able to replicate in detail the results which he has so far produced and push on to determine the effects of the level of distortion, lag, and other parameters on recognition of the prototype.

Keele, Fentress, and Posner have been investigating the ability of Ss to recognize new patterns after experience with a number of distortions of the same prototype. This work has been concerned primarily with the role of variability among the members of the category. The question is how does degree of variation within the instances which S views affect decisions concerning category membership of new patterns. The results obtained so far indicate that if people are trained on highly variable categories they are more inclusive in their classifications. High variability leads to classification of more new patterns as belonging to the category regardless of whether such classifications are correct or in error. Thus, the process of concept learning, as revealed by these experiments, not only involves learning individual exemples and abstraction of the "schema" but the learning of concept boundaries. Concept boundaries appear to be set by the variability of previous instances within the category. One promising method of separating the schema formation aspect of learning from the class boundary aspect is by use of the parameters signal detection theory. As would be expected, the sensitivity parameter (d') appears to improve the less the variable the category, while the criterion (β parameter) tends to drop as the category increases in variability. These studies are currently being replicated using the computer display.

The new computer system has allowed us not only to extend our sampling of patterns, but also to undertake some experiments in concept formation which have been impossible previously. In these studies the computer displays a set of distortions on the oscilloscope. After the presentation list, Ss see a matrix of light elements. Their task is to indicate the positions in the matrix where the dots of the prototype are most likely to occur. Preliminary data indicate that people can perform this task and the data seem to reflect more than a duplication of an individual pattern. The computer prints out the prototype and reproduction which S makes. These patterns can then be rated by other Ss for overall similarity. Figure 5 shows a few samples of the prototypes together with reproductions. Fentress and Keele plan to develop these studies during the summer months.

The study of abstraction can also be pursued with stimuli varying in a number of distinct attributes (e.g., shape, size, color, etc.). Schaeffer and Wallace (1968) have completed and submitted for publication a set of experiments on the learning of a conjunctive rule. In this study Ss learned a conjunction of four redundant and one independent attributes. They showed that the number of redundant attributes learned by Ss varied with the discriminability of the independent attribute. Subsequent experiments have shown that the inference about what was learned depends upon the sorting task to which S transferred at the end of learning. Increasing the salience of a redundant attribute in the transfer deck increases the likelihood that Ss will use that attribute as a basis for sorting the deck. The situation in which the concept is used has important effects upon the form of the concept.

Natural Languages

The analysis of natural language has been particularly refractory to psychological investigation. The reasons are the complexity of the associations which help us to understand the meaning of a particular word or sentence. Both Haller and Boies have begun to use the PDP-9 to similate some aspects of understanding words and sentences. Boies has developed a parsing program which allows the computer to interpret the meaning of new sentences and ask intelligible questions. The program accepts sentences which make sense within the context of the material presented previously and rejects questions which do not. While this program is still in a very early stage, Boies hopes to learn some of the operations on input which help in decoding new sentences. Haller is also planning to develop simulation programs on the PDP-9 which will be related to understanding words and sentences. It is hoped that within the next six months some preliminary results of these simulation efforts will be available.

In the meantime we continue to experiment on aspects of stimulus classification which may relate to the extraction of meaning. An extremely simple experimental approach to this problem has been incorporated in

experiments by Posner. These experiments involve the presentations of letter or digit stimuli and require S to respond as rapidly as possible whether a pair of stimuli is "same" or "different". However, unlike the experiments reported in the previous sections, they require fairly complex levels of classification. For example, "same" is defined as both stimuli being consonants or both stimuli being digits. In previous work Posner and Mitchell, (1967) it was found that vowel-consonant classification requires considerably longer than the time to classify two letters as having the same name. The structure of this classification is shown in Figure 6a. The long RT for the vowel-consonant classification does not itself indicate that the Ss are actually going through the name in order to arrive at the classification. The speeds indicate only that Ss have the opportunity to do so. This structure contrasts rather markedly with the classification letter-digit. For this classification the time to respond "same" is little if any longer than the time to respond that two letters have the same name (see Figure 6a). This result suggests that the Ss do not have the opportunity to go through the name in arriving at the classification letter-digit. In order to provide a converging operation, Posner found some letter pairs which are difficult to classify on the basis of the name. Consider the letter pairs Bb and Dd. If S is instructed to classify on the basis of the name, such pairs take longer than normal letter pairs. This is presumably because of the tendency to confuse b with d. If Ss must determine the name of a stimulus before being able to make a more complex classification, a letter pair involving b ought to take longer than other letter pairs. If, however, Ss are not going through the name and there is no need for them to resolve the difference between b and d, such "difficult" pairs should not require any longer reaction time. In the experiment, four difficult letters q, b, d, g were compared with four easy letters, h, m, r, f. Since all these are both letters and consonants, it is not necessary for Ss to distinguish between them in making either the letter-digit or vowel-consonant classification task. However, as shown in Figure 6b, the time to make a vowel-consonant classification is greater for difficult letters than it is for easy letters. However, the time to make a letter-digit classification is not greater for difficult letters than it is for easy letters. This suggests that in making the vowel-consonant distinction, Ss first have to determine the name of the letter before obtaining the class name. In the letter-digit case, this appears not to be required. For the vowel consonant distinction, the relevant stimulus is the name of the letter, while in the letter-digit task the relevant stimulus is the visual form.

These results suggest a number of possible explanations. One possibility is that the definition of a "vowel" is based on auditory or articulatory properties of letters while the definition of letter and digit is not. Another explanation is that the original learning of the letter-digit distinction is based upon separate visual experience with the two types of items. The original learning of the class vowel, however, is more likely to be as the result of a purely verbal explanation. The experience of seeing the vowels as an isolated visual set is probably rather rare. It should be possible to design studies which will distinguish between these explanations.

One practical, if somewhat remote, consequence of this result is to provide some theoretical support to the hypothesis often made in speed reading that one can go directly from the visual stimulation to complex associations or meaning responses without passing throug the name of the word. It is not easy to see how the technique used here might be applied to more complex kinds of associates such as would be involved in the meaning of words. However, it would be of great interest to try to develop this technique for application to the questions involved in speed reading.

Some current work by Schaeffer and Wallace is more closely related to the problems of reading than the technique presented above. The basic paradigm is to present Ss with a sentence and follow it with a picture which falsifies one element of the sentence. The reaction time for S to make a true or false judgment is measured. One variable of interest is the difference between active and passive sentences. Consider the sentences, "The boy hit the ball," and "The ball was hit by the boy." A sample question is will the active form lead to a faster rejection of a picture showing a girl hitting a ball? Conversely will the passive form give faster rejection of a picture showing a boy hitting a vase? Answers to these questions can tell us something about the levels of understanding of a sentence. It may indicate how the grammatical form tends to bias the mechanism underlying comprehension of the sentence. Preliminary experiments have suggested that the reaction time is quite sensitive to different aspects of the sentence grammar. It is expected that within the next few months additional data will be collected in this paradigm and a better evaluation will be possible of the sensitivity of this technique to various aspects of understanding.

During this year Keesey has been applying some earlier material developed by Dawes (1967) to the question of understanding of stories. In general Keesey has been looking at the occurrance of overgeneralizations and psuedodiscriminations in the recall of the stories. One interesting variable which he has begun to manipulate is whether the information relevant to a question is contained within a single sentence of the story or within more than one sentence. His preliminary results seem to indicate that transformations which require the combining of information from separate sentences tend to be more error prone than does information continued within a single sentence. There is some evidence that such transformations are more subject to overgeneralization than material presented within a single sentence. In preliminary work, Keesey studied performance of Ss required to read 50 or 100 words faster than their normal speed. During the summer Keesey hopes to determine the role of reading speed on error rate, simplification and transformation. It is hoped that these data will serve as the basis for his doctoral dissertation.

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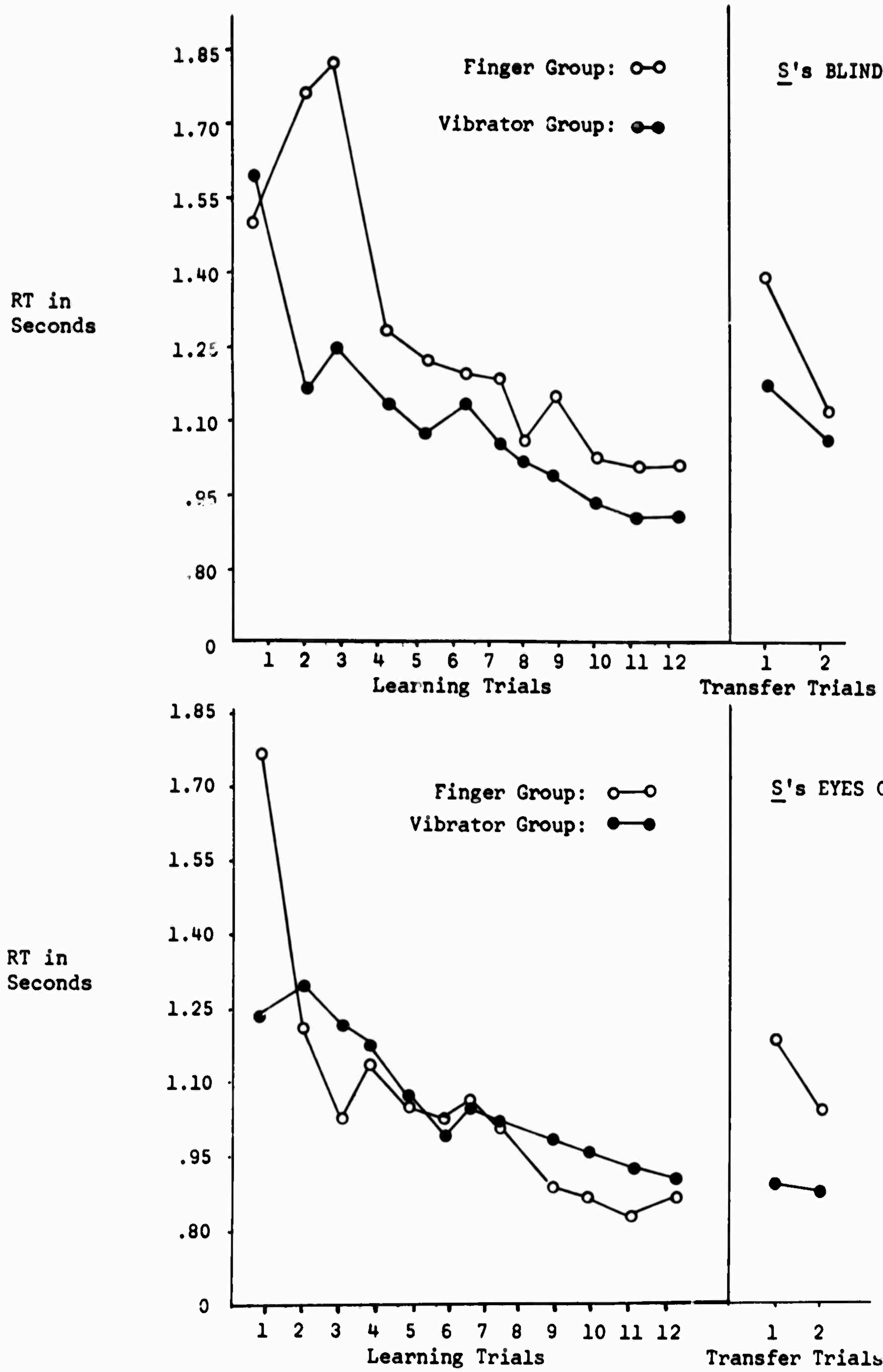


Figure 1

Reaction time to identify the correct vibrator for learning and transfer trials. Upper figure is for blindfolded Ss and lower figure for eyes open condition. (After Attneave & Benson, see text)

Figure 2

"Same" RT as a function of the number of letter pairs to be matched in the strings. Each point represents 288 trials (8 Ss, 2 days, 18 trials/day). (Eichelman, 1968)

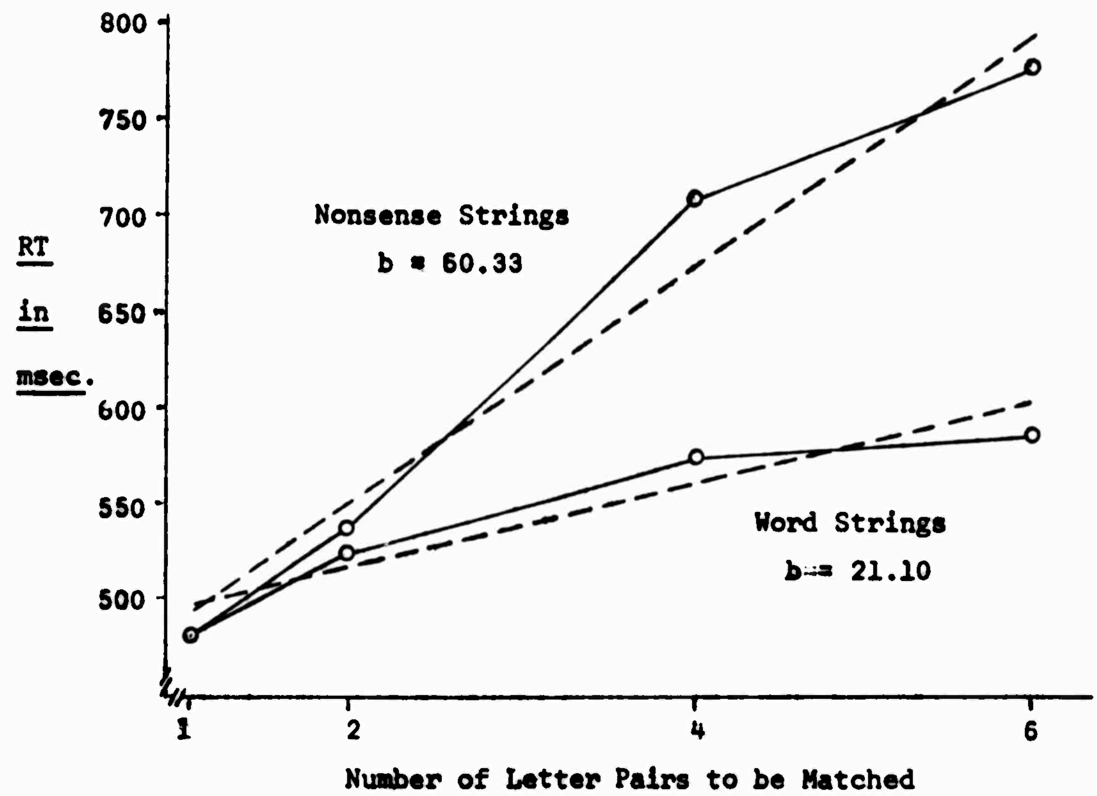


Figure 3

Reaction to time an extraneous signal as a function of position in the movement and size of target. (Posner & Keele, 1968 b)

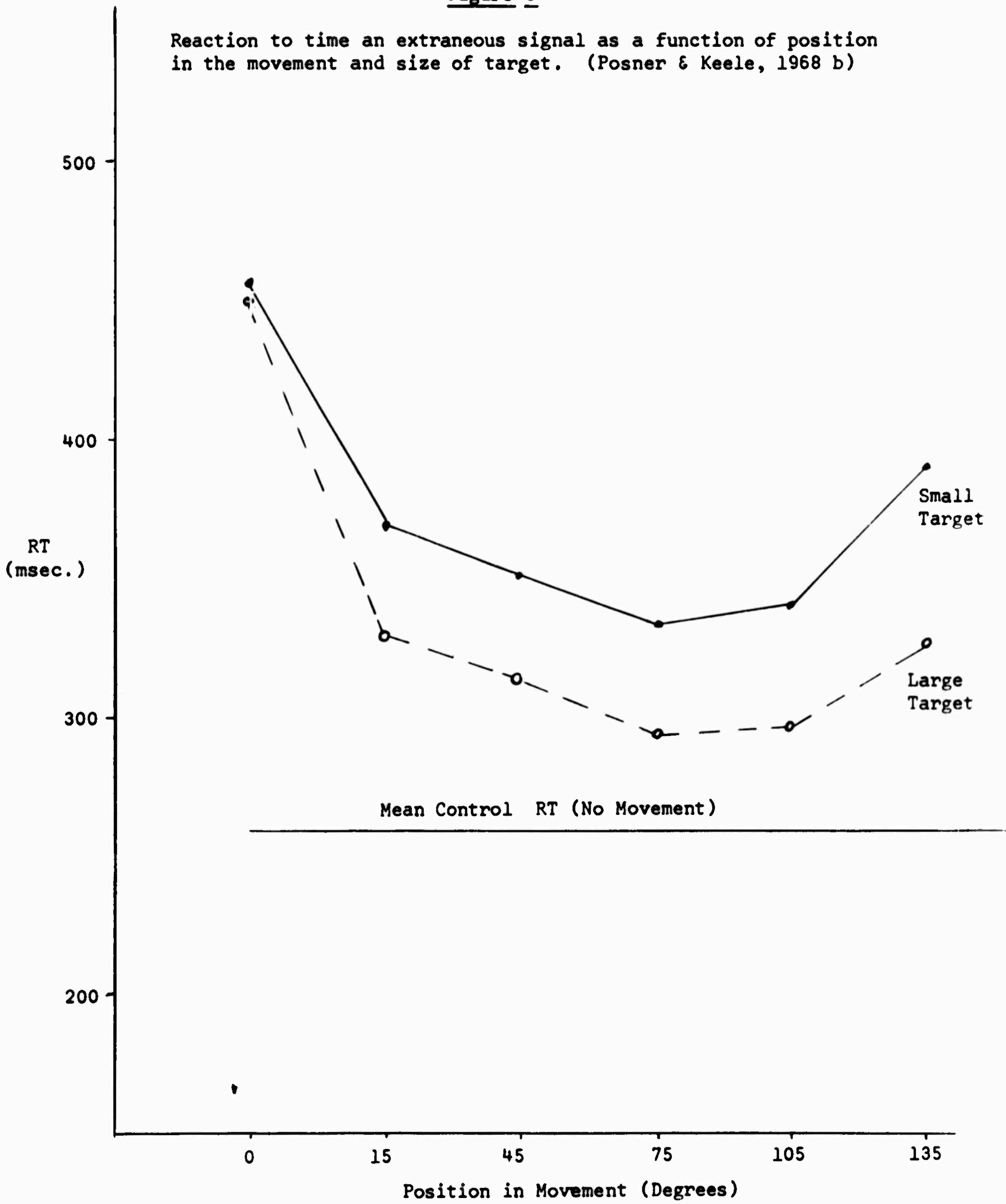


Figure 4

Pen record of blind movement to stops. Figure 4a is movement alone and 4b represents movement (lower trace) with a simultaneous key task (upper task) (see text).

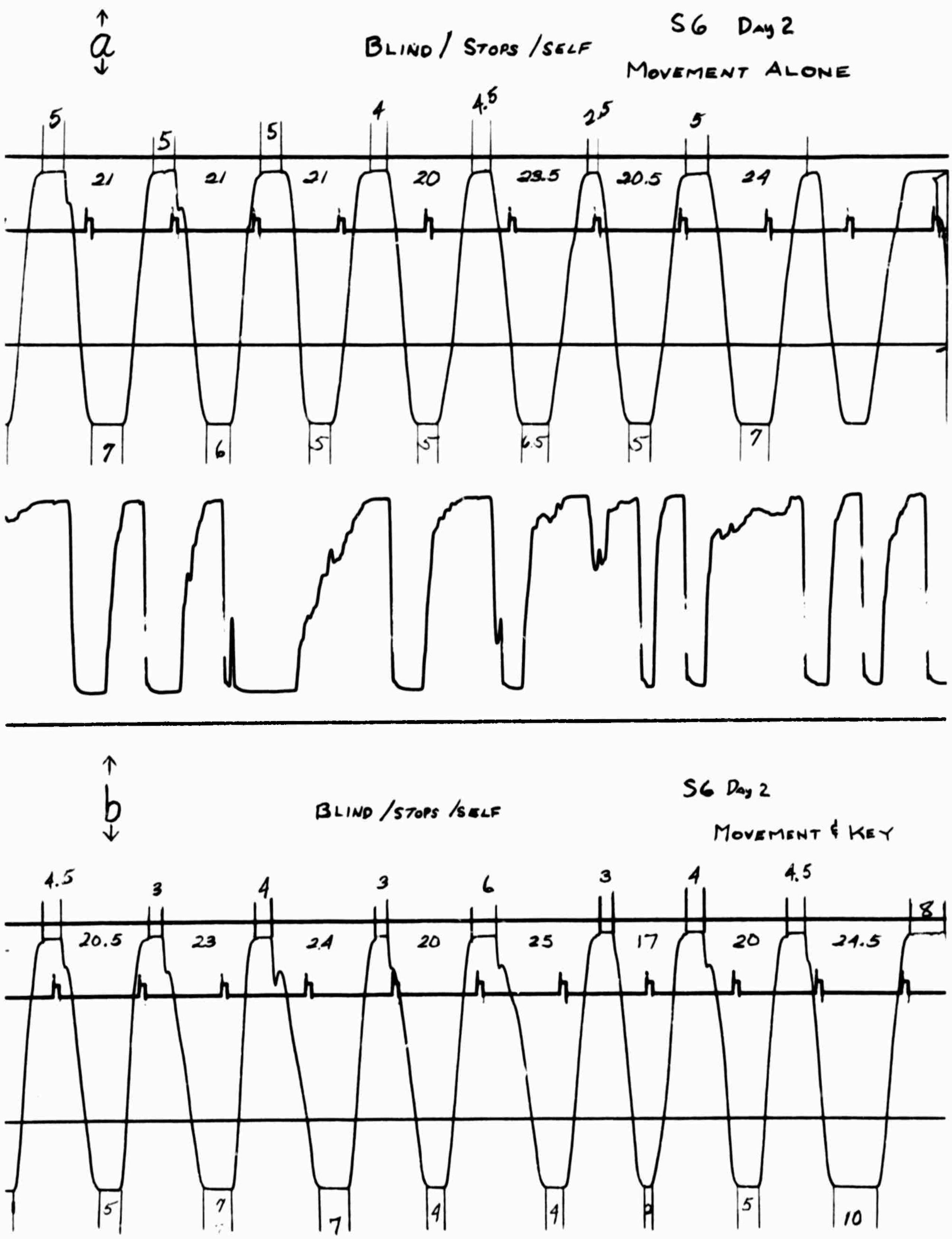


Figure 5

Left hand figures are prototypes of random dot pattern, while right hand figures are reproductions made by Ss who viewed a set of distortions. All figures are plotted directly by the PDP-9 computer teletype.

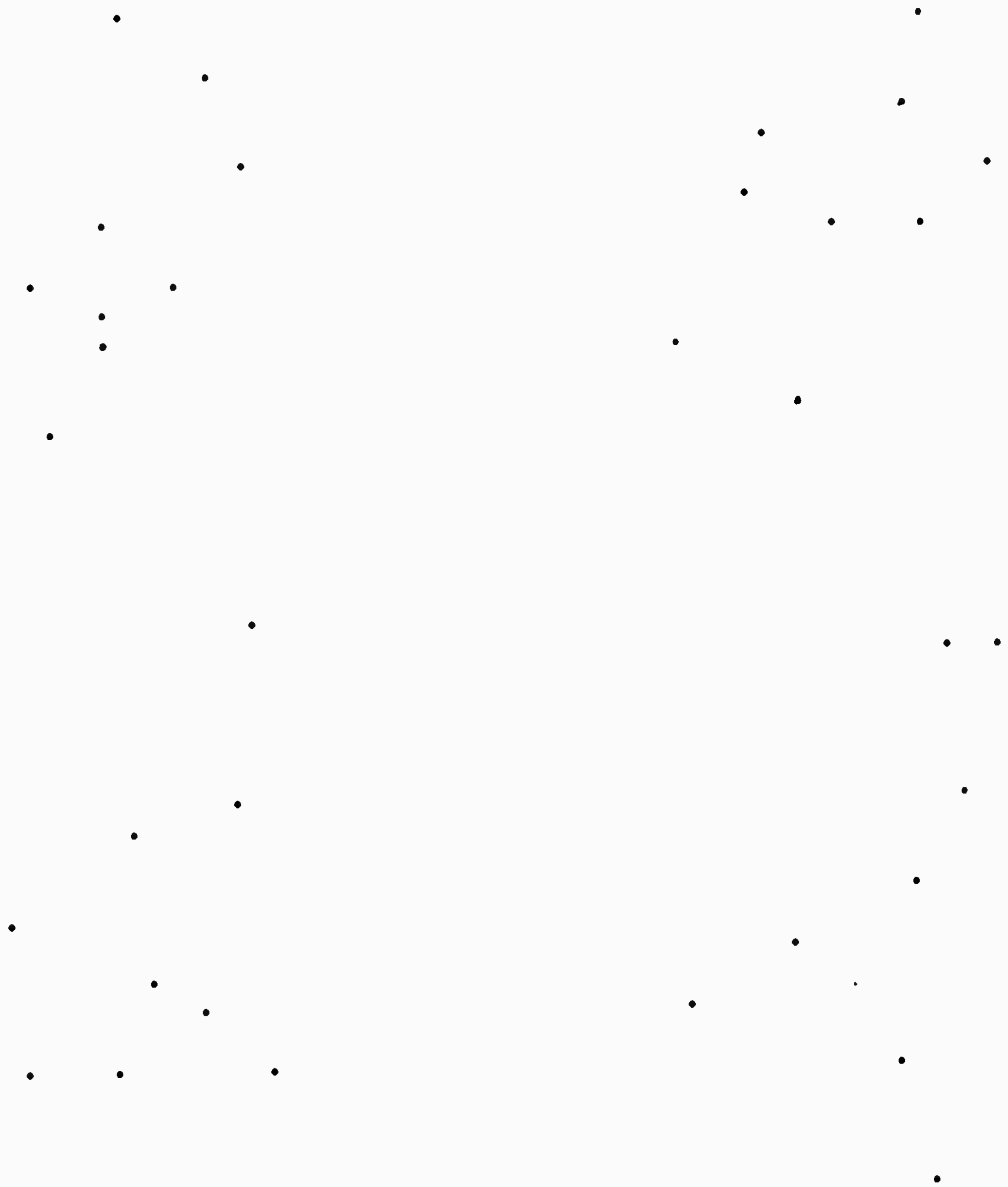
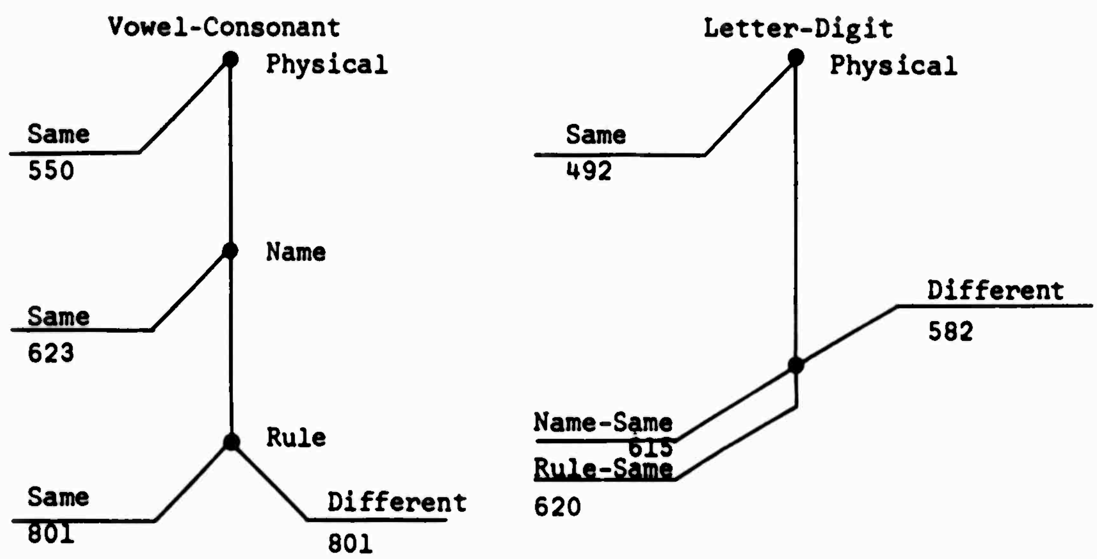


Figure 6

(a)



(b)

	Difficult	Easy
Name	Qq Bb Gg Dd	Rr Ff Hh Mm
VC	788	731
LD	666	660
Rule	q b g d p	Q B G D P
VC	850	810
LD	684	697

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13. ABSTRACT

During the second six months of our contract research we covered a wide diversity of research topics and experiments. However, there does seem to be an increasing unity underlying the efforts of our group. One focus is on the levels of processing which occur during the first few seconds after presentation of a stimulus. A second aspect is an interest in the analysis of meaning as it relates to familiar tasks such as listening and reading.

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